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Pedicelliops gen. nov., a new genus from West Africa with striking antennae (Ephemeroptera, Baetidae)

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Abstract

A new genus of Baetidae, *Pedicelliops* **gen. nov.**, and a new species, *P. capillifer* **sp. nov.**, are described from Guinea (West Africa) based on larvae. The new genus is characterized by having strongly enlarged pedicelli and very short flagella, a brush of dense, short setae between prostheca and mola of both mandibles, a small rectangular labrum, an apicolaterally pointed maxillary palp, a labial palp with a small distolateral protuberance and long setae ventrally on glossae and paraglossae. The femora of all legs are covered with numerous long, fine setae. The patellotibial suture is absent on the fore tibia and present on middle and hind tibiae. The claw is pointed with two rows of denticles. No spines are present on the posterior margins of the abdominal tergites. The imago remains unknown and the relationships with other African genera of Baetidae remains tentative. Despite being easily identifiable and of a fairly large size (body length ca. 5 mm), only two larvae were found in two highly sampled localities in West Africa.

Keywords

Filtering adaptation, Guinea, mayflies, Protopatellata, systematics

Introduction

The family Baetidae has the highest species diversity among mayflies, comprising ca. 1,100 species in 114 genera (updated from Sartori and Brittain 2015; Jacobus et al. 2019), which is close to one third of all mayfly species worldwide. They have a cosmopolitan distribution excluding Antarctica and New Zealand. Investigations of the

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molecular phylogeny of the order Ephemeroptera revealed the primitive status of the family (Ogden and Whiting 2005; Ogden et al. 2009). The generic diversity of Baetidae is the highest in the Afrotropical realm (ca. 40 genera), followed by the Neotropical (ca. 27 genera) and Oriental (ca. 26 genera) realms and finally the Nearctic (20 genera), Palaearctic (17 genera) and the Australasian (ca. 12 genera) realms (Gattolliat and Nieto 2009; Gattolliat 2012).

West Africa has attracted the attention of mayfly researchers for a long time and many collections and studies were done in that region. Between 1974 and 1989, the French ORSTOM (Office de la recherche scientifique et technique outre-mer), presently the IRD (Institut de Recherche pour le Développement), conducted field research in West Africa as part of an important onchocerciasis control program (Lévêque et al. 2003). Aquatic macroinvertebrates were collected in about 100 localities, mainly in Guinea, Ivory Coast, and Mali. Most localities were sampled regularly over a period of several years. As the systematics of aquatic insects was still poorly known at the time, important alpha taxonomic research was done and several articles were published including descriptions of new species and genera. The majority of mayflies known from West Africa were described based on material collected during this programme (e.g. Elouard and Forge 1978; Gillies 1980, 1989, 1993, 1997; Elouard 1986a, b; Elouard and Gillies 1989; Elouard and Hideux 1991; Gillies and Elouard 1990; Wuillot and Gillies 1993a, b, 1994; Gattolliat 2006; Gattolliat and Sartori 2006; Edia et al. 2015). However, only part of the material collected was sorted and identified. All the remaining unidentified material is now housed in the Museum of Zoology in Lausanne (Switzerland). The present study is based on larvae collected in 1985 and 1987 in two different locations in Guinea.

Materials and methods

The specimens were collected in 1985 and 1987 from two different areas of Guinea (West Africa). Specimens were preserved in 70–80% ethanol. Larvae were dissected in Cellosolve (2-Ethoxyethanol) with subsequent mounting on slides in liquid Euparal, using an Olympus SZX7 stereomicroscope.

Drawings were made using an Olympus BX43 microscope. Photographs of larvae were taken with a Canon EOS 6D camera and the Visionary Digital Passport imaging system (http://www.duninc.com). Images were processed using Adobe Photoshop Lightroom (https://adobe.com/ch_de/products/photoshop-lightroom) and Helicon Focus version 5.3 (http://www.heliconsoft.com). Photographs were subsequently enhanced with Adobe Photoshop Elements 13 (https://adobe.com/ch_de/products/photoshop).

Approximate GPS coordinates to sample locations were attributed using Google Earth (http://www.google.com/earth/download/ge/) and Elouard et al. (1990: fig.9) and distribution maps were generated with SimpleMappr (https://simplemappr.net, Shorthouse 2010).

The terminology used in the manuscript follows Hubbard (1995) and Kluge (2004).

Abbreviations

MZL Museum of Zoology Lausanne (Switzerland).

Results

***Pedicelliops* gen. nov.**
http://zoobank.org/0BD8D226-CC87-4807-9608-247830E581C5
Figures 1–7

Type species. *Pedicelliops capillifer* gen. et sp. nov., by present designation.

Diagnosis. *Larva.* This new genus is distinguished by the combination of the following characters: A) body elongate and slender, head clearly hypognathous (Figs 1, 2); B) base of antennae close to each other, with carina between them (Fig. 2d); C) antenna shorter than head length, with strong bilateral enlargement of pedicellus (Fig. 3a); D) labrum small and rectangular, distal margin with medial emargination and small, square process, dorsal surface with long, stout, simple setae, erratically distributed in distal part, not arranged in one arc (Fig. 4a); E) right mandible with a stick-like, apically denticulate prostheca and a brush of short, fine setae between prostheca and mola (Fig. 4b, c); F) left mandible with a robust prostheca, apically with a comb-shaped structure and with a brush of short, fine setae between prostheca and mola (Fig. 4d, e); G) hypopharynx with medial tuft of stout setae (Fig. 4g); H) maxillary palp 2-segmented (Fig. 4h); I) glossae basally broad, narrowing toward apex, slightly shorter than paraglossae, ventrolateral margin with a row of short, thin setae and a row of long, simple setae close to margin, apically with some robust, long, curved setae; stout paraglossae with convex outer margin and apex, ventrolateral margin with a row of long, simple setae; labial palps segment II with distolateral protuberance, directed distally, segment III conical (Fig. 4i, j); J) legs with many long, simple setae on margins and on both surfaces of femur, femoral patch absent on all legs, patellotibial suture absent on foreleg and present on middle and hind legs, claw robust and pointed, with two rows of denticles (Figs 5, 6); K) fore protoptera with a protuberance near inner margin (Fig. 2a, b); L) posterior margin of abdominal tergites I–VIII smooth without spines (Fig. 1a).

Imagines. Unknown.

Etymology. *Pedicelliops* is an arbitrary combination of letters with allusion to the Latin *pedicellus* and the Greek *iops*. *Pedicellus* is with reference to the striking second segment of the antennae and *iops* with reference to the Baetidae which look and move like small fishes. The gender is masculine.

Description. *Larva.* (Figs 1–6).

Body. Elongate and slender, head hypognathous (Figs 1, 2).

Head. *Antenna* (Figs 3a, b, 2c, d) shorter than head length with strong bilateral enlargement of pedicellus. Antennae bases in close proximity to each other, with small carina between them.

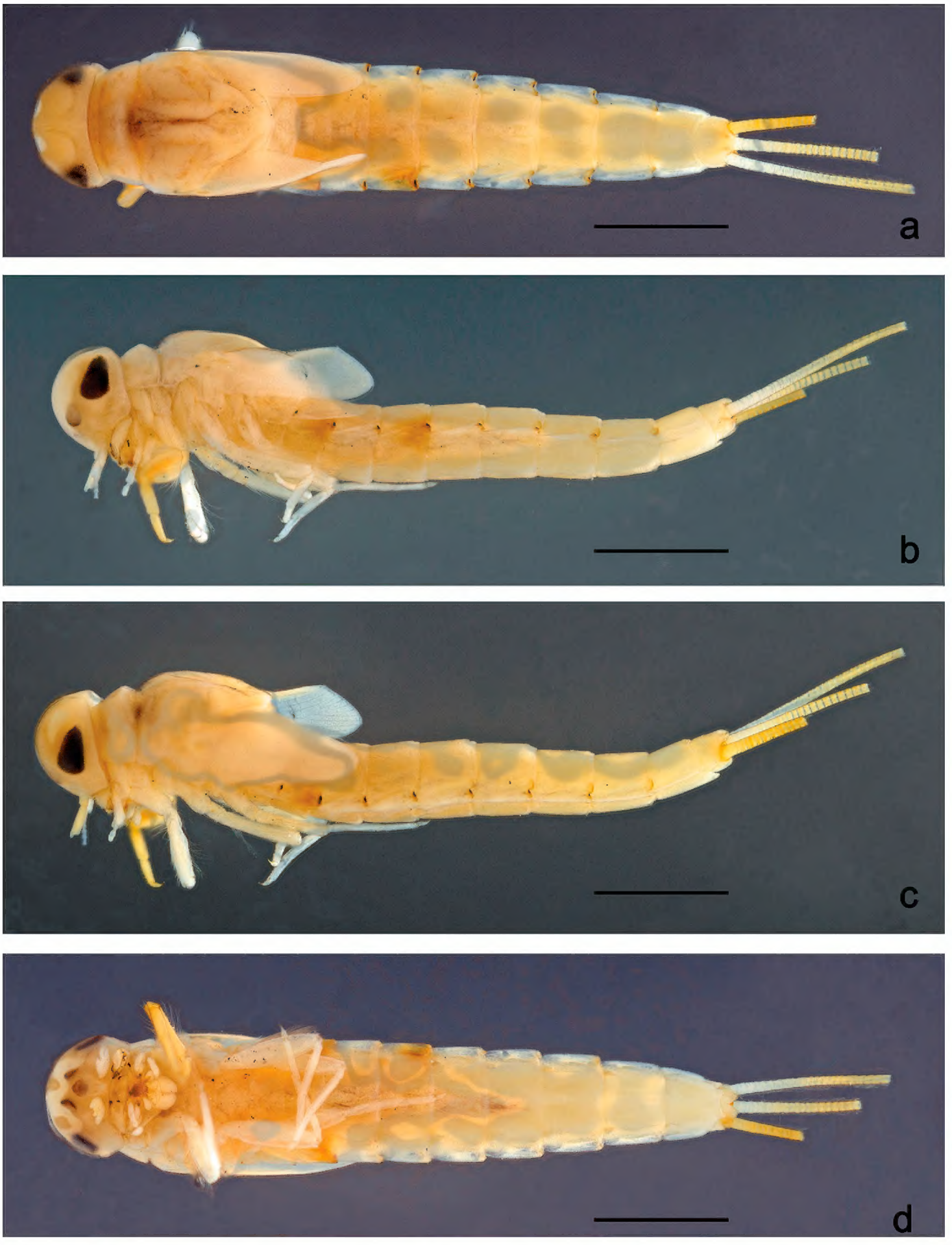

Figure 1. *Pedicelliops capillifer* gen. et sp. nov., habitus, larva **a** dorsal view **b, c** lateral views **d** ventral view. Scale bars: 1 mm.

Labrum (Fig. 4a). Small in comparison to other mouthparts, rectangular, wider than long; dorsal surface with long, stout, simple setae, erratically distributed in distal part, not arranged in one arc; ventrally with marginal row of setae composed of anterolateral long, simple setae and medial long, bifid setae.

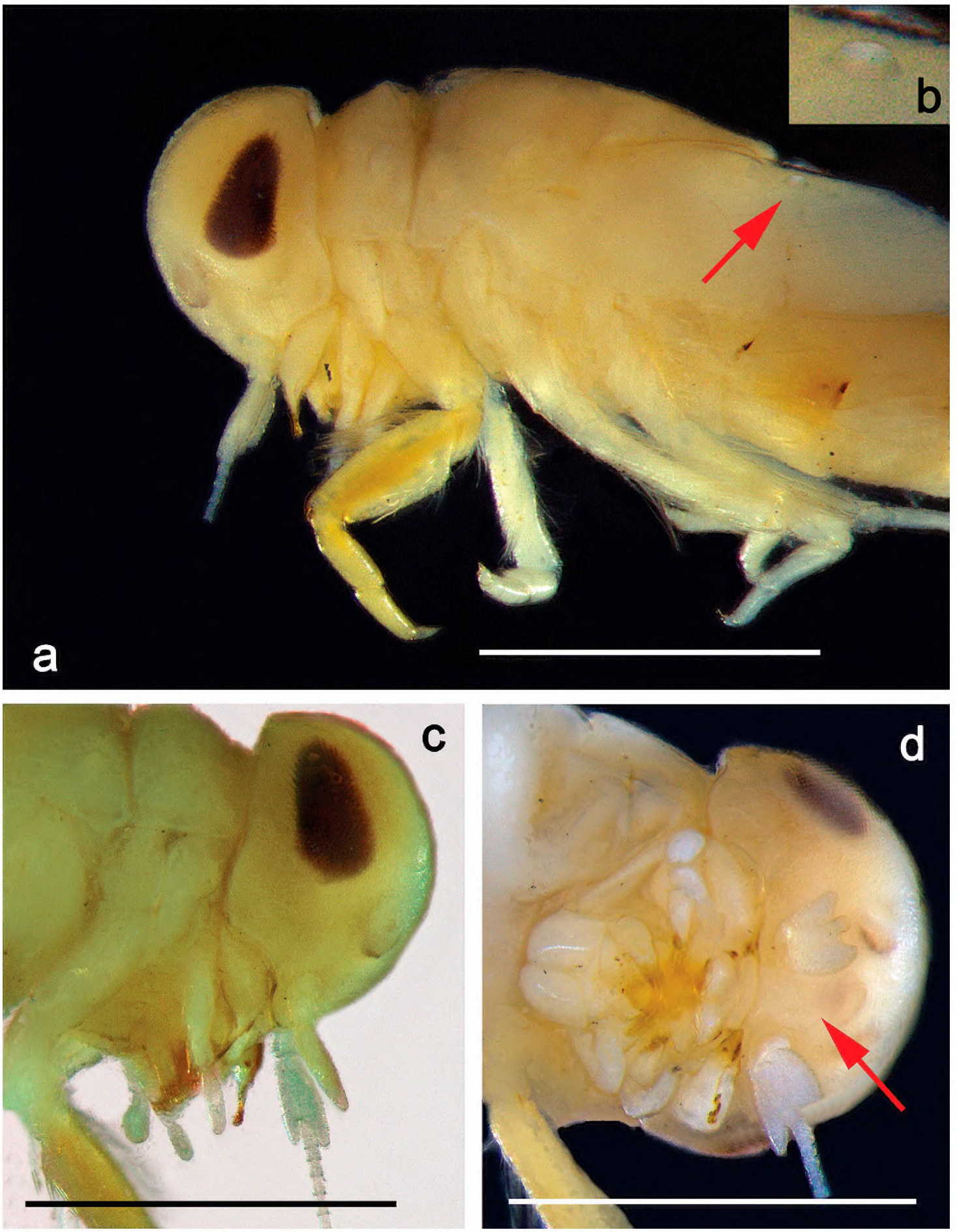

Figure 2. *Pedicelliops capillifer* gen. et sp. nov., larva morphology **a** head and thorax, lateral view **b** protuberance on fore protopteron **c** head, lateral view **d** head, ventral view (arrow: carina). Scale bars: 1 mm.

Right mandible (Fig. 4b, c). Incisor and kinetodontium fused, both with well-developed denticles; inner margin of innermost denticle without a row of thin setae; prostheca stick-like, apically denticulate; margin between prostheca and mola with a brush of abundant, short, fine setae.

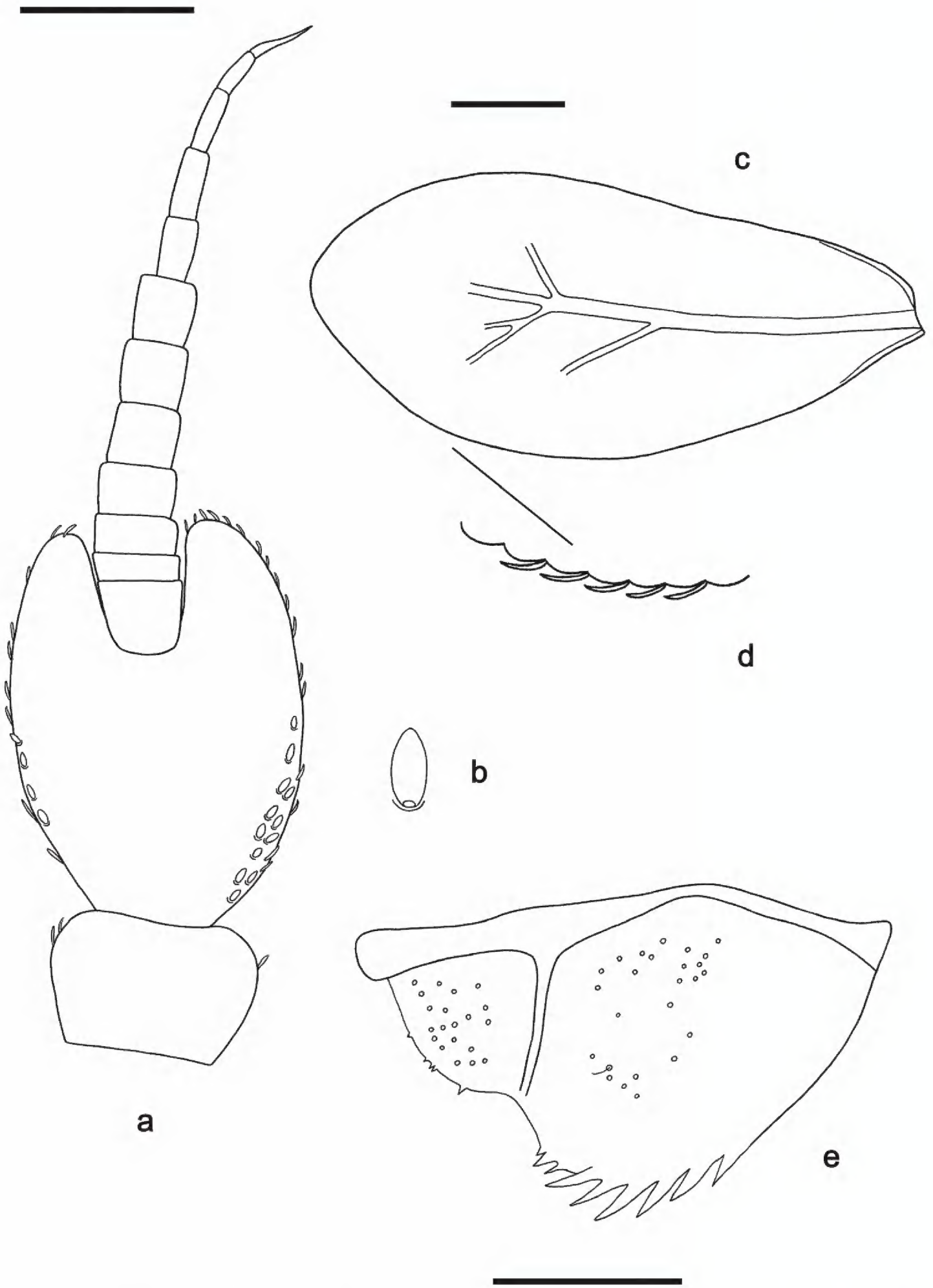

Figure 3. *Pedicelliops capillifer* gen. et sp. nov., larva morphology **a** antenna **b** scale of pedicellus **c** gill I **d** margin of gill I **e** paraproct. Scale bars: 0.1 mm.

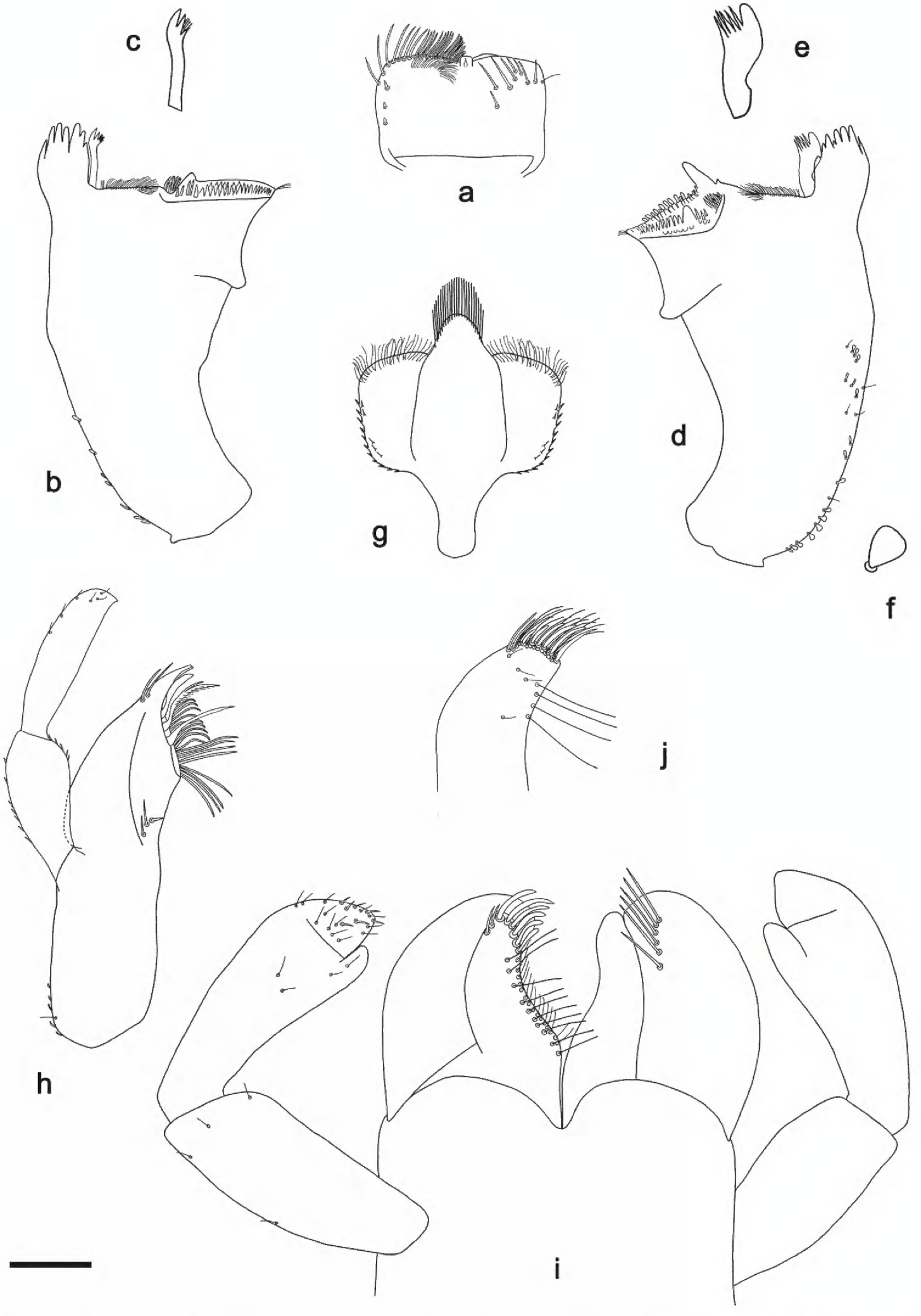

Figure 4. *Pedicelliops capillifer* gen. et sp. nov., larva morphology **a** labrum **b** right mandible **c** right prostheca **d** left mandible **e** left prostheca **f** seta on left mandible **g** hypopharynx and superlinguae **h** maxilla **i** labium (left: ventral view, right: dorsal view) **j** paraglossa (ventral view). Scale bar: 0.1 mm.

Left mandible (Fig. 4d–f). Incisor and kinetodontium fused, both with well-developed denticles; prostheca robust, apically with comb-shaped structure; margin between prostheca and mola with a brush of abundant, short, fine setae.

Hypopharynx (Fig. 4g). With a dorsomedial tuft of stout setae on lingua.

Maxilla (Fig. 4h). Apically with three stout canines and three denti-setae; distal denti-seta tooth-like, following same direction as canines, other denti-setae slender, bifid and pectinate; maxillary palp with two segments.

Labium (Fig. 4i, j). Glossae basally broad, narrowing toward apex, slightly shorter than paraglossae; ventrolateral margin with a row of short, thin setae and a row of long, simple setae close to inner margin, apically with some robust, long, curved setae. Paraglossae with convex outer margin and apex; ventrolateral margin with a row of long, simple setae; apical margin with three rows of long, stout setae (Fig. 4j). Labial palps segment II with distolateral protuberance, segment III conical.

Thorax. *Fore protoptera* (Fig. 2a, b). With a protuberance near inner margin.

Hind protoptera. Absent.

Foreleg (Figs 5a–c, 6a). *Femur* with many long, simple setae on dorsal and ventral margins and on both lateral surfaces; femoral patch absent; apex of femur with ventral lobe poorly developed; patellotibial suture absent; *claw* robust and pointed, with two divergent rows of denticles.

Middle and hind legs (Figs 5d–f, 6b, c). More slender than foreleg; *femur* with same setation as foreleg; femoral patch absent; anterior outer projection of femur apex directed towards the inner side of femur (Fig. 5d); patellotibial suture present; *claw* as in foreleg.

Abdomen. *Tergites.* Posterior margin of segments I–VIII smooth, without spines.

Gills (Fig. 3c, d). Seven pairs of gills on segments I–VII, dorsally oriented.

Paraproct (Fig. 3e). Without prolongation at posterior margin, with stout, marginal spines; cercotractor with few minute, marginal spines.

Caudal filaments (Fig. 1a, d). Inner margin of cerci with 2– 18 long, thin setae per segment, increasing in number distally; paracercus bilaterally with 3 to more than 12 long, thin setae per segment, increasing in number distally. Paracercus not reduced, but broken.

Description. ***Imagines.*** Unknown.

Distribution (Fig. 7). West Africa: Guinea.

Pedicelliops capillifer **gen. et sp. nov.**

http://zoobank.org/1A749009-4120-46F5-B79A-DEACAC30AF56

Figures 1–7

Diagnosis. ***Larva.*** As the genus is monospecific, it is difficult to propose a relevant specific diagnosis. We can presume specific differences in the shape of the labial and maxillary palps, and in the setation of the forefemur. Species with less derived characters (shape of the pedicel, reduction of the labrum) may also be expected.

Etymology. With reference to the remarkable setation found ventrally on the glossae and paraglossae, and on the femora.

Type-material. ***Holotype.*** Guinea • larva; Bas. Niger, River Niandan, Loc. Sassambaya; ca. 400 m; 25.i.1985; leg. J.-M. Elouard; on slides; GBIFCH 00592365, GBIFCH 00592366; thorax and abdomen in alcohol; GBIFCH 00515518; MZL. ***Paratype.*** Guinea • larva; Boussoulé, Milo River; ca. 360 m; 14.iv.1987; leg. J.-M. Elouard; on slides; GBIFCH 00592319, GBIFCH 00592320; MZL.

Description. ***Larva.*** (Figs 1–6). *Body length* 5.2 mm.

Colouration (Fig. 1a–d). Colouration strongly altered due to long term storage of the larvae in alcohol, with the cuticle becoming transparent. Head, thorax and abdomen dorsally brown, fore protoptera ecru. Head, thorax and abdomen light brown ventrally. Legs and caudalii light brown.

Head. *Antenna* (Fig. 3a, b). Short, ca. 2/3 of head length. Pedicellus bilaterally strongly enlarged and distally elongate on both sides. Scapus and pedicellus laterally with ovoid scales.

Labrum (Fig. 4a). Length 0.6× maximum width. Distal margin with medial emargination and a small, square process. Dorsal surface with long, stout, simple setae, erratically distributed in distal part, not arranged in one arc. Ventrally with marginal row of setae composed of anterolateral long, simple setae and medial long, bifid setae. Ventral surface with ca. three short, spine-like setae near lateral margin.

Right mandible (Fig. 4b, c). Incisor with four denticles; kinetodontium with three denticles. Margin between prostheca and mola straight; with setae along whole margin from prostheca to mola, shorter than 1/5 of prostheca. Tuft of setae present at apex of mola.

Left mandible (Fig. 4d–f). Incisor with five denticles; kinetodontium with three denticles. Margin between prostheca and mola straight; with setae along whole margin, shorter than 1/5 of prostheca, and a minute denticle toward subtriangular process. Subtriangular process long and slender, above level of area between prostheca and mola. Tuft of setae present at apex of mola.

Both mandibles with lateral margins convex. Basal half laterally with small, spatulate setae.

Hypopharynx and superlinguae (Fig. 4g). Lingua longer than wide and longer than superlinguae; with well-developed medial tuft of stout setae. Superlinguae distally rounded, lateral margins straight; long, fine, simple setae along distal margin.

Maxilla (Fig. 4h). Galea-lacinia ventrally with two simple, apical setae under canines. Medially with one spine-like seta and two short, simple setae. Maxillary palp ca. 1.3× as long as length of galea-lacinia; palp segment II 1.3× length of segment I; segment I widening in distal part; short, fine, simple setae scattered over distal part of surface of segment II; segment I laterally with short, robust setae; apex of segment II laterally pointed.

Labium (Fig. 4i, j). Inner margin of glossa with a row of short, fine, simple setae; ventral surface with a row of long, fine, simple setae close to margin; apex with six long, robust setae, curved toward inner side, and two shorter, spine-like setae; outer margin bare. Paraglossa with outer margin and apex convex and inner margin concave, slightly curved inward; ventrally with three rows of long, robust setae in apical area, four short, fine, simple setae in anteromedial area and a row of four long, simple setae on margin;

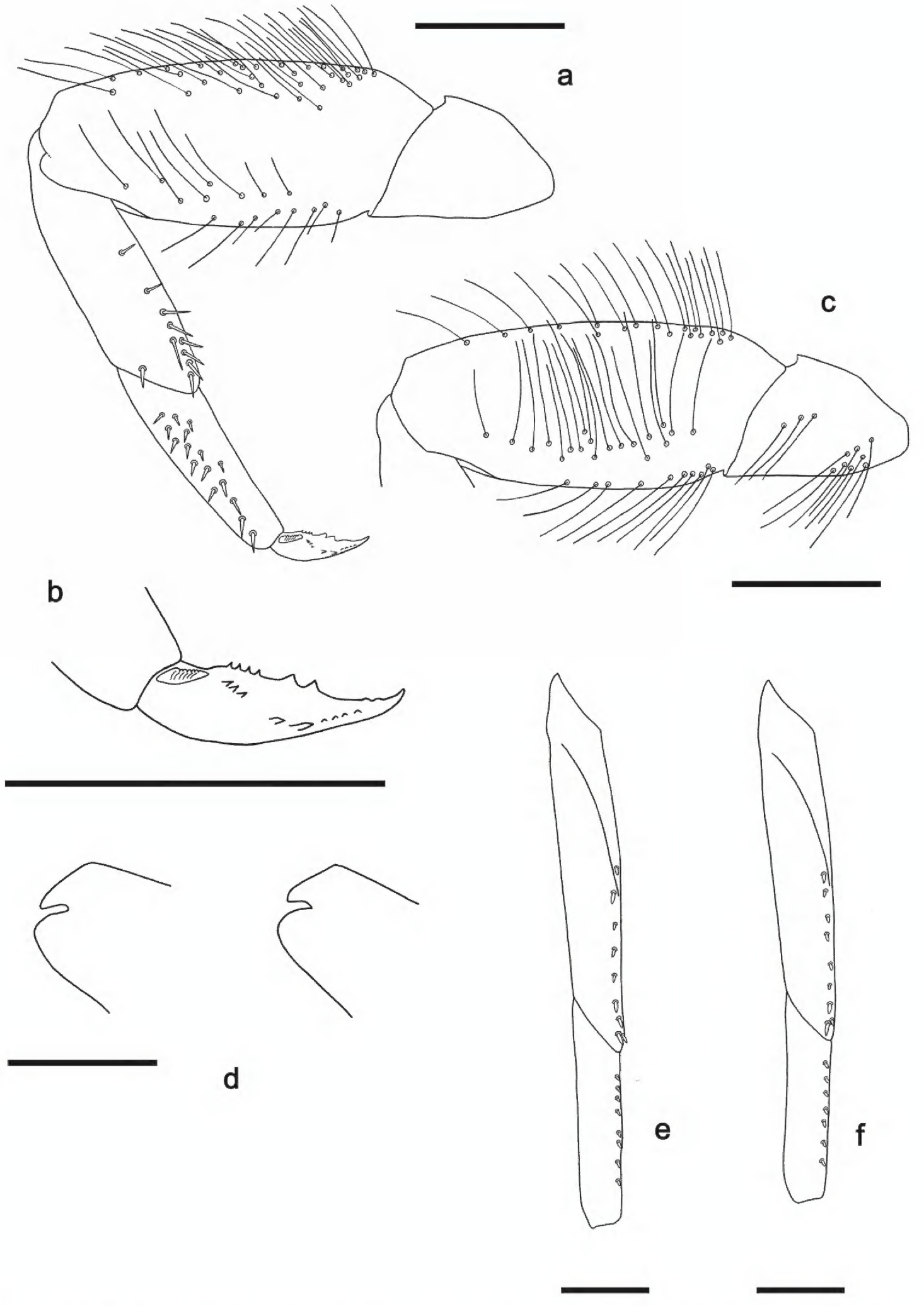

Figure 5. *Pedicelliops capillifer* gen. et sp. nov., larva morphology **a** foreleg (anterior view) **b** fore claw **c** fore femur and trochanter (posterior view) **d** apex of middle and hind femur **e** middle tibia and tarsus **f** hind tibia and tarsus. Scale bars: 0.2 mm.

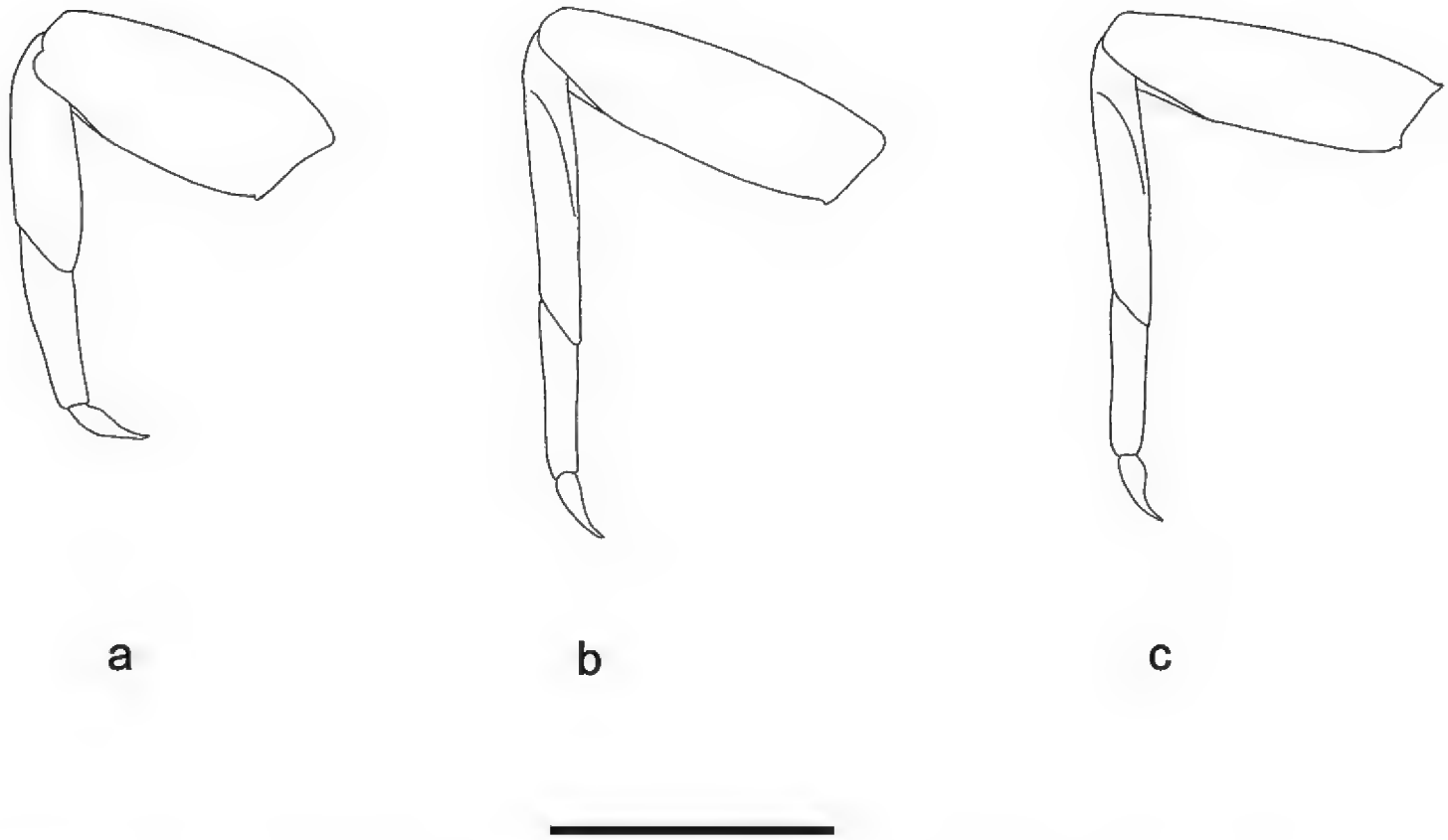

Figure 6. *Pedicelliops capillifer* gen. et sp. nov., larva morphology: **a** foreleg **b** middle leg **c** hind leg. Scale bar: 0.5 mm.

dorsally with a row of six long, spine-like setae near inner margin. Labial palp with segment I 0.9× length of segments II and III combined. Segment I with few short, fine, simple setae ventrally. Segment II with slender, distolateral protuberance, directed distad; distomedial protuberance 0.3× width of base of segment III; ventral surface with short, fine, simple setae; dorsally without spine-like setae near outer margin. Segment III conical; length 0.8× width; ventrally covered with short, spine-like setae and short, fine, simple setae.

Thorax. *Fore protoptera* (Fig. 2a, b). With a protuberance near inner margin.

Hind protoptera. Absent.

Foreleg (Figs 5a–c, 6a). Ratio of foreleg segments 1.4: 1.0: 0.8: 0.4. *Femur.* Broad, length ca. 2× maximum width. With many long, simple setae on dorsal and ventral margins as well as on anterior and posterior surface; length of setae mostly ca. 0.6× maximum width of femur; femoral patch absent. *Tibia.* Dorsal margin bare; with a row of medium, spine-like setae along ventral margin; one medium, spine-like seta at distomedial margin. Patellotibial suture absent. *Tarsus.* Dorsal and ventral margins bare, with short to medium, spine-like setae scattered over surface. *Claw* robust and distally pointed, with two divergent rows of denticles; denticles with different sizes, two apical denticles clearly larger than other denticles; subapical setae absent (Fig. 2b).

Middle and hind leg (Figs 5d, e, 6b, c). Ratio of middle and hind leg segments 1.2: 1.0: 0.6: 0.3. *Femur.* Length ca. 3× maximum width. With same setation as foreleg; femoral patch absent. *Tibia.* Dorsal margin bare. Ventral margin margin with a row of short, spine-like setae. Patellotibial suture present on basal ½ area. *Tarsus.* Dorsal margin bare. Ventral margin with a row of short, spine-like setae. *Claw* as foreleg.

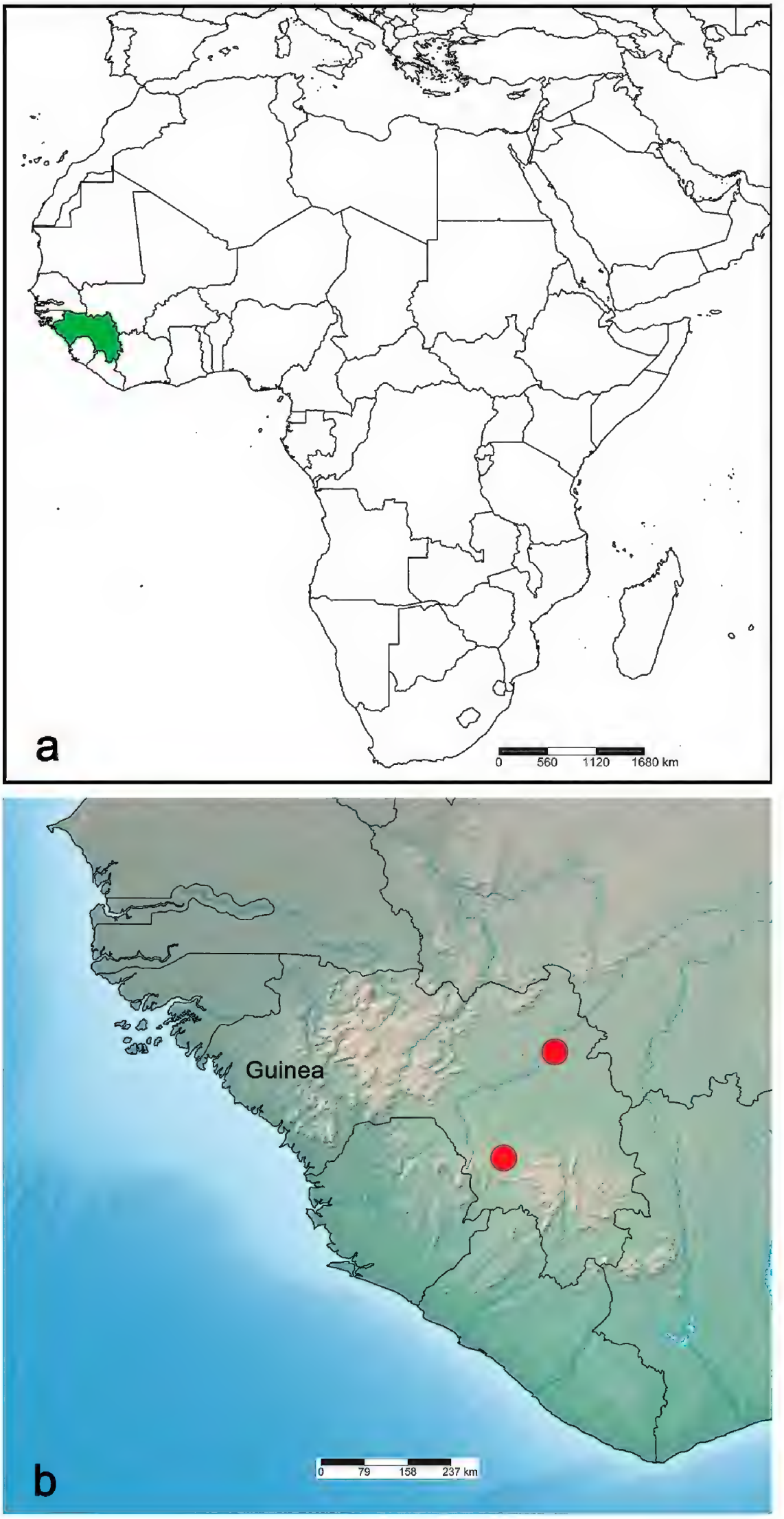

Figure 7. *Pedicelliops capillifer* gen. et sp. nov., distribution **a** Africa, green: Guinea **b** Guinea.

Abdomen. *Gills* (Fig. 3c, d). Seven pairs of gills on segments I–VII. Margin undulated, with short, stout, curved setae. Tracheae partly extending from main trunk to inner and outer margins. Gill I as long as the length of segments II and 2/3 of III combined. Gills II–VII unknown.

Paraproct (Fig. 3e). With nine stout, marginal spines. Surface scattered with micropores. Cercotractor with convex margin and a few minute, marginal spines.

Distribution. West Africa: Guinea (Fig. 7).

Discussion

Pedicelliops gen. nov. clearly belongs to the family Baetidae based on the long, slender, pisciform body shape; the labrum with distinctly expressed median incision; the shape of the right and left prostheca; the fused incisor and kinetodontium of both mandibles; the shape of the glossae (basally widened, most part narrow); and the anterior outer projection of the femur apex, which is directed toward the inner side of the femur (middle and hind legs only, in fore femur not like this; Fig. 5a, d) (Wang and McCafferty 1996; Kluge 2004). The new genus can be assigned to the Protopatellata according to the rank free system of Kluge (Kluge 1997; Kluge and Novikova 2011), based on the absence of a patellotibial suture in the foreleg and its presence in middle and hind legs of the larva. The following characters differentiate *Pedicelliops* gen. nov. from all other genera of Protopatellata: short antennae with bilaterally strongly enlarged pedicelli (Fig. 3a); small labrum in comparison to other mouthparts (Fig. 4); labium with long and short setae on ventral surface of glossae and paraglossae and the labial palps with a distolateral protuberance (Fig. 4i, j), directed distad; and femora of all legs with long setation on dorsal and ventral margins as well as on anterior and posterior surfaces (Fig. 5a, b). From the illustrations, it appears that *Micksiops bicaudatus* (Gillies, 1990) also has glossae and paraglossae with short and long setae on ventral side (Gillies 1990: fig. 91), but labrum, mandibles, maxillae and legs are dissimilar to *Pedicelliops* gen. nov. *Bugilliesia sudanensis* (Ulmer, 1916), *B. grisea* (Gillies, 1990) and *B. guineensis* (Gillies, 1990) similarly have long setae ventrolaterally on the paraglossae, the labial palp segments II have a distolateral protuberance, both mandibles have a brush of setae between prostheca and mola, and incisors and kinetodontium of both mandibles are fused. However, labrum, maxillary palps and legs are dissimilar (Gillies 1990: figs 67–70, 74–81, 84). Knowledge of the imaginal stages, especially of the male genitalia is of major importance to confirm the possible relationship of *Pedicelliops* gen. nov. with Rhithrocloeoninae (sensu Kluge 2012b). Indeed, *Bugilliesia* Lugo-Ortiz & McCafferty, 1996, and related genera belonging to this subfamily, possess a unique character: the loss of the last segment of the gonostylus. Most other African genera of Protopatellata were previously assigned to the *Centroptiloides* complex (Lugo-Ortiz and McCafferty 1998). This complex also includes highly adapted taxa such as the carnivorous genera *Nesoptiloides* Demoulin, 1973 or *Barnumus* McCafferty & Lugo-Ortiz, 1998. Most genera of this complex have the right incisor and kinetodontium

only partially fused and the claws have two rows of denticles increasing in size progressively. Protopatellata are mainly distributed in the Afrotropics, with the exception of *Indocloeon* Müller-Liebenau, 1982, with a large repartition in the Oriental realm (Kluge 2012a; Kaltenbach and Gattolliat 2017; Kluge and Chanaporn 2020). As seen in *Pedicelliops* gen. nov., *Indocloeon* also generally presents labial palps with a distolateral protuberance, setae between prostheca and mola, and claws with two rows of denticles, with the apical denticles strongly enlarged. However, *Indocloeon* does not present any of the peculiar adaptations of *Pedicelliops* gen. nov. as listed above.

The genus *Varipes* Lugo-Ortiz & McCafferty, 1998 from South America also has femora and trochanters with long, dense setae (including transverse rows of setae, which are absent in *Pedicelliops* gen. nov.), claws with two rows of denticles and labial palp segments II with a distolateral protuberance. However, as the two genera differ in many other aspects and as *Varipes* is not part of the Protopatellata (Dominguez et al. 2006), the similarities are most certainly due to convergence.

Pedicelliops capillifer gen. et sp. nov. has protuberances close to the inner margin of the fore protoptera (Fig. 2a, b). Comparable structures are described from a few other Baetidae as well: *Monocentroptilum badium* (Kopelke, 1980) from East Africa has a pair of small protuberances on the mesonotum (Kluge 2018: fig. 1), *Asiobaetodes eloi* Gattolliat, 2012 from Borneo has paired protuberances on the pronotum and on the base of the inner margin of the fore protoptera (Gattolliat 2012: fig. 17) and the Neotropical *Paracloeodes binodulus* Lugo-Ortiz & McCafferty, 1996 has small protuberances between the fore protoptera (Dominguez et al. 2006: fig. 55O).

The remarkable long and dense setation of the femora of all legs and ventrally on glossae and paraglossae probably represent adaptations for filtering by *Pedicelliops capillifer* gen. et sp. nov. This type of foraging is known or assumed from cases across various families of mayflies (e.g. Oligoneuriidae, Isonychiidae) (Sartori and Brittain 2015), but also from some Baetidae (e.g. *Ophelmatostoma camerunense* (Ulmer, 1920), *Pseudopannota bertrandi* (Demoulin, 1967), *Guajirolus* Flowers, 1985) (Waltz and McCafferty 1987; Dominguez et al. 2006).

The description of *Pedicelliops* gen. nov. is based on only two larvae, which were collected over three decades ago. Remarkably, these larvae were found in the two most regularly sampled localities by the ORSTOM team in West Africa (around fifty visits over the years 1984 to 1987). Most of the material from this region was studied by one of the authors (Gattolliat 2006), and because of its large size and its ease of recognition, we can assume that no additional material was overlooked. It could mean that this species is extremely rare, or it occurs in microhabitats which were not or only rarely sampled and the two specimens were collected by chance. Alternatively, the species may be prone to deteriorating environmental conditions over the last decades.

The number of localities and different habitats sampled in West Africa are limited and there are still vast regions where no collection activities have occurred. It would be prudent to assume that the number of genera and species of Baetidae will continue to increase with further field work and collections in these regions.

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References

Dominguez E, Molineri C, Pescador ML, Hubbard MD, Nieto C (2006) Ephemeroptera of South America. In: Adis J, Arias JR, Rueda-Delgado G, Wantzen KM (Eds) Aquatic Biodiversity in Latin America, Vol. 2. Pensoft Publishers, Sofia-Moscow, 646 pp.

Edia OE, Diétoa YM, Konan KF, Bony KY, Diomandé D (2015) Aquatic insect community structure in four coastal streams (Côte d'Ivoire, West Africa). Journal of Chemical, Biological and Physical Sciences, Section D 5: 1022–1037.

Elouard J-M (1986a) Éphémères d'Afrique de l'Ouest: Le genre *Afromera* (Ephemeridae). Revue d'Hydrobiologie Tropicale 19: 169–176.

Elouard J-M (1986b) Éphémères d'Afrique de l'Ouest: Le genre *Eatonica* (Ephemeridae). Revue d'Hydrobiologie Tropicale 19: 87–92.

Elouard J-M, Forge P (1978) Émergence et activité de vol nocturne de quelques espèces d'Ephéméroptères de Côte d'Ivoire. Cahier O.R.S.T.O.M. Serie Hydrobiologie 12: 187–196.

Elouard J-M, Gillies MT (1989) West African Ephemeroptera. The genus *Machadorythus* (Tricorythidae). Aquatic Insects 11(1): 1–10. https://doi.org/10.1080/01650428909361340

Elouard J-M, Hideux P (1991) Mayflies of West Africa. *Thraulobaetodes*, an atypical new genus of crawling Baetidae. In: Alba-Tercedor J, Sanchez-Ortega A (Eds) Overview and Strategies of Ephemeroptera and Plecoptera. Sandhill Crane Press, Gainesville, 169–174.

Elouard J-M, Gillies MT, Wuillot J (1990) Ephemeroptera from West Africa: The genus *Pseudopannota* (Baetidae). Revue d'Hydrobiologie Tropicale 23: 27–39.

Gattolliat J-L (2006) *Bugilliesia* Lugo-Ortiz and McCafferty and allied genera (Baetidae, Ephemeroptera), with emphasis on West African fauna. Mitteilungen der Schweizerische Entomologische Gesellschaft 79: 281–298.

Gattolliat J-L (2012) Two new genera of Baetidae (Ephemeroptera) from Borneo (East Kalimantan, Indonesia). Annales de Limnologie – International. Journal of Limnology 48(2): 187–199. https://doi.org/10.1051/limn/2012012

Gattolliat J-L, Nieto C (2009) The family Baetidae (Insecta: Ephemeroptera): synthesis and future challenges. Aquatic Insects 31(sup1): 41–62. https://doi.org/10.1080/01650420902812214

Gattolliat J-L, Sartori M (2006) The mayflies of Ghana (Insecta: Ephemeroptera). Annale Historico-naturales Musei Nationalis Hungarici 98: 5–28.

Gillies MT (1980) An introduction to the study of *Cloeon* Leach (Baetidae, Ephemeroptera) in West Africa. Bulletin de l'Institut Français d'Afrique Noire 42: 135–156.

Gillies MT (1989) Occurrence of *Rhithrocloeon* (Baetidae: Ephemeroptera) in West Africa. Revue d'Hydrobiologie Tropicale 22: 287–288.

Gillies MT (1990) A revision of the African species of *Centroptilum* Eaton (Baetidae, Ephemeroptera). Aquatic Insects 12(2): 97–128. https://doi.org/10.1080/01650429009361395

Gillies MT (1993) Descriptions of some Afrotropical Baetidae (Ephemeroptera) II. *Baetis* Leach, s.l., West African species. Aquatic Insects 15(4): 213–223. https://doi.org/10.1080/01650429309361522

Gillies MT (1997) A new species of *Procloeon* Bengtsson from the forest zone of West Africa (Ephemeroptera, Baetidae). Entomologist's Monthly Magazine 133: 247–250.

Gillies MT, Elouard J-M (1990) The mayfly-mussel association, a new example from the River Niger basin. In: Campbell IC (Ed.) Mayflies and Stoneflies: Life histories and biology. Kluwer Academic Publishers, Dordrecht, 289–297. https://doi.org/10.1007/978-94-009-2397-3_35

Hubbard MD (1995) Towards a standard methodology for the description of mayflies (Ephemeroptera). In: Corkum LD, Ciborowski JJH (Eds) Current directions in research on Ephemeroptera. Canadian Scholar's Press, Toronto, 361–369.

Jacobus LM, Macadam CR, Sartori M (2019) Mayflies (Ephemeroptera) and their contributions to ecosystem services. Insects 10(6): 1–26. https://doi.org/10.3390/insects10060170

Kaltenbach T, Gattolliat J-L (2017) New species of *Indocloeon* Müller-Liebenau from South-East Asia (Ephemeroptera, Baetidae). ZooKeys 723: 43–60. https://doi.org/10.3897/zookeys.723.20578

Kluge NJ (1997) Classification and phylogeny of the Baetidae (Ephemeroptera) with description of the new species from the Upper Cretaceous resins of Taimyr. In: Landolt P, Sartori M (Eds) Ephemeroptera & Plecoptera. Biology-Ecology-Systematics. Proc. VIII Int. Conf. on Ephemeroptera and XII Int. Symposium on Plecoptera, Lausanne (Switzerland), August 1995. Mauron, Tinguely & Lacht SA, Fribourg, 527–535.

Kluge NJ (2004) The Phylogenetic System of Ephemeroptera. Kluwer Academic Publishers, Dordrecht, 442 pp. https://doi.org/10.1007/978-94-007-0872-3

Kluge NJ (2012a) Non-African representatives of the plesiomorphion Protopatellata (Ephemeroptera: Baetidae). Russian Entomological Journal 20(1): 361–376. https://doi.org/10.15298/rusentj.20.4.02

Kluge NJ (2012b) Systematics of Rhithrocloeoninae with new species from Uganda. Russian Entomological Journal 21(1): 1–13. https://doi.org/10.15298/rusentj.21.1.01

Kluge NJ (2018) A new Afrotropical genus *Monocentroptilum* gen. nov. (Ephemeroptera: Baetidae: Protopatellata). Zootaxa 4486(2): 115–128. https://doi.org/10.11646/zootaxa.4486.2.2

Kluge NJ, Chanaporn S (2020) Review of the Oriental genus *Indocloeon* Müller-Liebenau 1982 (Ephemeroptera: Baetidae) with descriptions of two new species. Zootaxa 4779(4): 451–484. https://doi.org/10.11646/zootaxa.4779.4.1

Kluge NJ, Novikova EA (2011) Systematics of the mayfly taxon *Acentrella* (Ephemeroptera, Baetidae), with description of new Asian and African species. Russian Entomological Journal 20(1): 1–56. https://doi.org/10.15298/rusentj.20.1.01

Lévêque C, Hougard JM, Resh V, Statzner B, Yameogo L (2003) Freshwater ecology and biodiversity in the tropics: What did we learn from 30 years of onchocerciasis control and the associated biomonitoring of West African rivers? Hydrobiologia 500(1–3): 23–49. https://doi.org/10.1023/A:1024660017077

Lugo-Ortiz CR, McCafferty WP (1998) The *Centroptiloides* complex of Afrotropical small minnow mayflies (Ephemeroptera: Baetidae). Annals of the Entomological Society of America 91(1): 1–26. https://doi.org/10.1093/aesa/91.1.1

Ogden TH, Whiting MF (2005) Phylogeny of Ephemeroptera (mayflies) based on molecular evidence. Molecular Phylogenetics and Evolution 37(3): 625–643. https://doi.org/10.1016/j.ympev.2005.08.008

Ogden TH, Gattolliat J-L, Sartori M, Staniczek AH, Soldan T, Whiting MF (2009) Towards a new paradigm in mayfly phylogeny (Ephemeroptera): Combined analysis of morphological and molecular data. Systematic Entomology 34(4): 616–634. https://doi.org/10.1111/j.1365-3113.2009.00488.x

Sartori M, Brittain JE (2015) Order Ephemeroptera. In: Thorp J, Rogers DC (Eds) Ecology and general biology: Thorp and Covich's Freshwater Invertebrates. Academic Press, 873–891. https://doi.org/10.1016/B978-0-12-385026-3.00034-6

Shorthouse DP (2010) SimpleMappr, an online tool to produce publication-quality point maps. https://www.simplemappr.net [Accessed August 03, 2020]

Waltz RD, McCafferty WP (1987) New genera of Baetidae (Ephemeroptera) from Africa. Proceedings of the Entomological Society of Washington 89: 95–99.

Wang T-Q, McCafferty WP (1996) New diagnostic characters for the mayfly family Baetidae (Ephemeroptera). Entomological News 107: 207–212.

Wuillot J, Gillies MT (1993a) *Cheleocloeon*, a new genus of Baetidae (Ephemeroptera) from West Africa. Revue d'Hydrobiologie Tropicale 26: 213–217.

Wuillot J, Gillies MT (1993b) New species of *Afroptilum* (Baetidae, Ephemeroptera) from West Africa. Revue d'Hydrobiologie Tropicale 26: 269–277.

Wuillot J, Gillies MT (1994) *Dicentroptilum*, a new genus of mayflies (Baetidae, Ephemeroptera) from Africa. Aquatic Insects 16(3): 133–140. https://doi.org/10.1080/01650429409361547